



King Saud University  
The Saudi Dental Journal

[www.ksu.edu.sa](http://www.ksu.edu.sa)  
[www.sciencedirect.com](http://www.sciencedirect.com)



## REVIEW ARTICLE

# How effective the problem-based learning (PBL) in dental education. A critical review



Ali Alrahlah \*

*Restorative Dental Sciences Department, College of Dentistry, King Saud University, Riyadh, Saudi Arabia*

Received 24 April 2016; revised 7 August 2016; accepted 23 August 2016

Available online 18 October 2016

## KEYWORDS

Dental education;  
Problem-based learning;  
Effectiveness;  
Critical review

**Abstract** The purpose of this critical review is to explore the research supporting the effectiveness of problem-based learning (PBL) as a teaching method in dental education. PBL was developed more than 40 years ago in reaction to the problems and limitations of traditional teaching approaches. Here, aspects of the PBL teaching approach are reviewed, and the reasons for the substantial effect of this approach on dental education are discussed. Evidence shows that students in PBL-based courses exhibit superior professional skills and effective learning compared with those instructed using traditional approaches.

© 2016 The Author. Production and hosting by Elsevier B.V. on behalf of King Saud University. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

## Contents

1. Introduction . . . . .	156
2. Definition of PBL . . . . .	156
3. Effective teaching and the PBL approach . . . . .	156
4. Education, theory, and psychology underlying PBL . . . . .	157
4.1. The activation-elaboration theory. . . . .	157
4.2. The situational interest theory . . . . .	157
5. PBL features and process . . . . .	157
6. Advantages and disadvantages of PBL . . . . .	158
7. PBL characteristics . . . . .	158
8. PBL and student motivation. . . . .	159

\* Address: Department of Restorative Dental Sciences, College of Dentistry, King Saud University, P.O. Box 60169, Riyadh 11545, Saudi Arabia.

E-mail address: [aalrahlah@ksu.edu.sa](mailto:aalrahlah@ksu.edu.sa).

Peer review under responsibility of King Saud University.



Production and hosting by Elsevier

<http://dx.doi.org/10.1016/j.sdentj.2016.08.003>

1013-9052 © 2016 The Author. Production and hosting by Elsevier B.V. on behalf of King Saud University.

This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

9. The tutor's role in PBL .....	159
10. Assessing PBL .....	159
11. Effectiveness of PBL .....	160
12. Summary .....	160
Conflict of interest .....	160
References .....	161

## 1. Introduction

The quality and effectiveness of university education are of major concern to university administrators (Devlin and Samarawickrema, 2010). Recently, some dental schools in Saudi Arabia have proposed the use of a new curriculum based on a student-centered, rather than teacher-centered, approach. This curriculum is designed to promote self-learning and life-long learning. Patient cases are used in a collaborative learning model, such as one employing problem-based learning (PBL), as a central focus to provide relevance to the topics covered in lectures, seminars, and laboratory courses (Rahman, 2011).

Although the effectiveness of teaching is best estimated in association with individual goals, some characteristics of teaching are highly demanded, as demonstrated by agreement among faculty members and evidence of student learning. A method considered to be effective in one situation may not be in another. For example, a very good lecture that provides the answer to a problem may be counted as an effective method when the goal is solely to provide knowledge. However, when the goal is to motivate students to develop an answer to a specific problem, then this well-designed lecture may be considered to be ineffective. Stimulating students to think by focusing their attention on a particular problem, rather than confusing them, is important (Atkins and Brown, 2002).

The various teaching methods used in medical and dental schools include lectures, small-group teaching, and laboratory sessions. PBL, a small-group teaching approach, requires students to use information to solve a problem, which is more effective than learning by reading or listening. In this approach, students are more active and thus can develop a variety of skills, such as teamwork, problem formulation, information finding, discussion and explanation of new information to others, decision making, and conclusion formulation (Polyzois et al., 2010; Wood, 2004; Onyon, 2012). PBL is now used in many higher-education institutes globally, and it has been shown to be superior to more traditional methods (Dennick and Exley, 2004).

PBL was introduced to replace traditional teaching methods in health care schools. The concept was developed in the late 1960s in the School of Medicine at McMaster University in Canada. PBL has spread throughout the world to institutes such as the University of New Mexico in the United States and University of Limburg at Maastricht in the Netherlands. The implementation of PBL expanded steadily during the 1970s and 1980s, and a large number of medical schools had approved PBL as an essential part of their curricula by the 1990s. It is currently implemented in many areas of health education, such as dentistry, pharmacy, and nursing, in universities worldwide (Polyzois et al., 2010). In this review, the

claims made for the effectiveness of PBL as a teaching approach are explored.

## 2. Definition of PBL

Barrows and Tamblyn (1980) defined PBL simply as “the learning which results from the process of working toward the understanding of, or resolution of a problem” (Barrows and Tamblyn, 1980, p. 18). The students’ tutor guided them to work on clinical and biomedical problems (O’Grady et al., 2012).

PBL was developed in response to the problems and limitations of traditional teaching approaches. It is an encouraging way to learn, as students work with problems that are challenging and observed in their real life. Students realize that the learning needed to solve and understand existing problems is valuable (Barrows, 2002).

PBL has been introduced and developed into an important teaching method by which students gain the skills, knowledge, and attitude, and it is an important part of many curricula. Three characteristics of PBL distinguish it from traditional teaching approaches (Walton and Matthews, 1989). First, the curriculum is organized around problems, instead of disciplines, and the emphasis is on integrated learning, instead of separation into basic and clinical science components. Second, it is dominated by conditions that simplify learning, such as small-group teaching, a student-centered approach, active study, and independent learning. Third, it is determined by outcomes, such as improved functional knowledge, development of the skills and motivation needed for lifelong learning, and the development of self-assessment skills.

## 3. Effective teaching and the PBL approach

Biggs and Tang (2011) defined effective teaching as “getting most students to use the level of cognitive processes needed to achieve the intended outcomes that the more academic students use spontaneously” (Biggs and Tang, 2011, p.4). Effective teaching is well known to be directed and focused on how students learn (Devlin and Samarawickrema, 2010).

How effectively faculty members teach depends on what they think teaching is. Three levels of thinking about teaching have been recognized. The first two levels are known as blaming models, which consist of blaming the student and the teacher, respectively. The third model incorporates learning and teaching, and considers effective teaching to motivate students to use learning activities to achieve learning outcomes. Students may use lower levels of cognitive learning activities than required to achieve outcomes, which leads to a superficial approach to learning, or they can use high-level activities suitable for accomplishing proposed outcomes, leading to a deep

learning approach. Effective teaching supports suitable learning activities and does not support unsuitable ones (Biggs and Tang, 2011).

The dominant goal of the PBL approach is to show students the relevance of the subject matter by placing it in a suitable and realistic practical context. In addition, PBL is constructed to promote numerous required learning outcomes and goals, including: (1) helping students build a wide and flexible knowledge base, (2) helping students become effective collaborators, (3) improving effective problem-solving skills, (4) motivating students to learn intrinsically, and (5) developing self-directed learning skills. PBL has been applied in many programs and fields across many levels of education worldwide; it can be considered to be “one of the few curriculum-wide educational innovations surviving since the 1960s” (Loyens et al., 2011; Bridges et al., 2012, p. 3).

#### 4. Education, theory, and psychology underlying PBL

The performance of students taught using PBL tends to fluctuate slightly, according to examination scores, and some researchers have claimed that the theoretical basis of PBL is dubious. PBL usually forms part or all of health and medical school curriculum content. Thus, tutors' engagement with educational theory that supports this teaching method and understanding of how it can help students in their future jobs are important (Onyon, 2012).

##### 4.1. The activation-elaboration theory

The activation-elaboration theory has three features: activation of prior knowledge, elaboration and context matching to enhance memory, and information recall. Prior knowledge determines what can be learned about a problem. Its activation helps new learners by simulating links between new and old information (Onyon, 2012; Schmidt, 1993). A problem involving the underlying physiology and pathology of medical condition can facilitate the retention of new knowledge by building on previously acquired relevant basic knowledge. Problem solving in the context of small-group teaching has been shown to activate prior knowledge, thereby facilitating the handling of new information (Onyon, 2012).

##### 4.2. The situational interest theory

The situational interest theory underlying PBL holds that problem solving makes students willing to grasp additional information about a given topic, increasing their focus and willingness to learn. Situational interest refers to stimulation by a captivating or attractive problem in a given situation. The psychological processes underlying the need to learn can be explained by inconsistency theory, proposed by investigators of epistemic curiosity. People seem to have a natural affinity to learn about the world when they face something that they do not know about or that lies beyond their expectations. Thus, they experience situational interest, which allows them to realize the knowledge gap between previous knowledge and what they currently want to know. This situation has been referred to as a cognitively induced experience of lack of knowledge. It initiates knowledge-seeking behavior, which aims to identify the knowledge gap through the integration

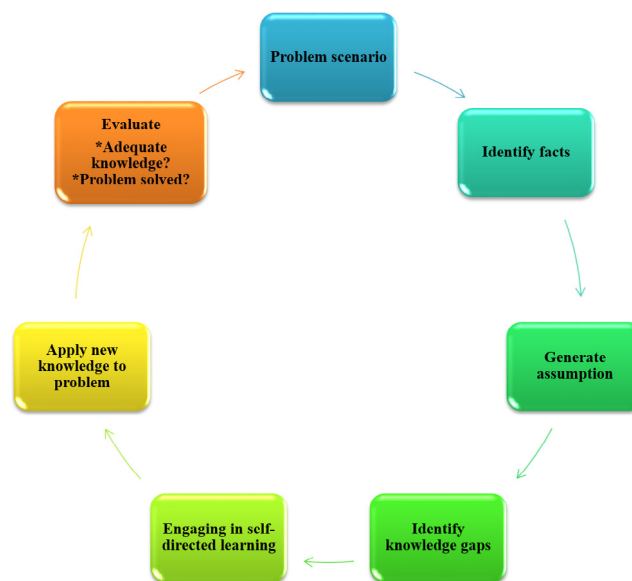


Figure 1 The PBL cycle.

of new knowledge into present knowledge structures (Schmidt et al., 2011).

#### 5. PBL features and process

Several features of PBL are key in attaining set goals: the inclusive PBL tutorial process, facilitation, the problems used, self-directed learning, collaboration, and post-problem reflection. A PBL tutorial session begins with the provision of information about a complex problem to a group of students. Students must gain further information about the problem; they may collect evidence by performing experiments or doing other research. At some stage in the investigation of the problem, students normally suspend what they are doing to review and think about the information they have gathered in their initial search; they then try to generate questions about that information, and make assumptions about primary cause that may help to explain the problem. Thereafter, students can formulate ideas or concepts, which requires additional learning with the purpose of solving the problem. After considering the problem with their gathered knowledge, the students divide up and independently research the problems they have identified. They then regroup to share what they have learned, and to review their assumptions or generate new assumptions to gain new knowledge. At the end of the PBL session, students go through the problem reflection or feedback stage to summarize the lessons being taught and consider their performance in collaborative problem solving and self-directed learning. Finally, the students assess their understanding of the problem and their progress toward a solution (Bridges et al., 2012). The PBL cycle is shown in Fig. 1.

In an ideal PBL process, students start by identifying the nature of the problem; they must then expand their knowledge about it and work toward finding an effective solution. This process requires a structured and systematic approach; students are, therefore, motivated to present the problem in a positive systematic way. The ideal PBL process consists of the following five steps (Campbell and Norton, 2009).

**Table 1** Advantages and disadvantages of PBL (Wood, 2003).

Advantages of PBL	Disadvantages of PBL
<i>Student centered PBL:</i> It fosters active learning, improved understanding, and retention and development of lifelong learning skills	<i>Tutors who cannot "teach":</i> Tutors enjoy passing on their own knowledge and understanding so may find PBL facilitation difficult and frustrating
<i>Generic competencies:</i> PBL allows students to develop generic skills and attitudes desirable in their future practice	<i>Human resources:</i> More staff have to take part in the tutoring process
<i>Integration:</i> PBL facilitates an integrated core curriculum.	<i>Other resources:</i> Large numbers of students need to access the same library and computer resources simultaneously
<i>Motivation:</i> PBL is fun for students and tutors, and the process requires all students to be engaged in the learning process	<i>Role models:</i> Students may be deprived access to a particular inspirational teacher who in a traditional curriculum would deliver lectures to a large group
<i>"Deep" learning:</i> PBL fosters deep learning (students interact with the learning materials, relate concepts to everyday activities, and improve their understanding).	<i>Information overload:</i> Students may be unsure about self-directed study
<i>Constructivist approach:</i> Students activate prior knowledge and build upon	

Step 1: Groups are formed. Students are initiated into the fundamentals of this instructional approach and its meaning to them individually. They start to identify differences between traditional teaching methods and PBL. Then, the role of the tutor/facilitator is clarified. The groups agree on fundamental rules of behavior within the group and manage their roles. The importance of the leader and scribe are specifically emphasized.

Step 2: Groups start on their first task by trying to understand the problem. They argue from the perspective of their present knowledge and experience: what is known? What is not known? Students agree on a common view of the problem, identify gaps in their knowledge, and decide what needs to be explored and who will do which part of the research.

Step 3: Students independently report the results of their research to the group. This report must be a clear summary and be linked to the group's understanding of what the problem is.

Step 4: Students review their new knowledge and reflect on what it means in terms of their perception of the problem. New gaps in their knowledge are identified. Other research needs are also identified and met by one member of each group.

Step 5: The process continues until the students are able to formulate a suitable answer to the problem.

## 6. Advantages and disadvantages of PBL

Advantages of PBL over traditional approaches include improved integration of basic and clinical skills; improved

communication, teamwork, and self-directed learning; and improved motivation and enjoyment of working together on a problem. For example, for tutors in health education, this integrated approach gains when linking clinical cases with basic science, by preparing students to solve clinical problems based on basic principles and previous knowledge. Furthermore, skills learned and experienced in the process of PBL, such as teamwork, delegation, and the use of relevant literature to solve a clinical problem, are important for professional work after graduation (Onyon, 2012).

Learning to work in the PBL group is another important life skill. Group learning also provides chances for students to network, exchange ideas and knowledge, and respect different views. Students may learn best by teaching each other, and working in groups provides them with the chance to polish their knowledge and obtain it in other ways. Furthermore, learners gain more knowledge in groups than in other teaching settings, perhaps because they are more engaged and involved in the learning process (Savin-Baden and Major, 2004). Table 1 summarizes the advantages and disadvantages of PBL.

## 7. PBL characteristics

Traditional teaching approaches often follow a linear path, whereby the tutor orders what is to be done. S/he presents detailed information about a particular topic, and students then solve the given problem. In PBL, the problem is presented first and students then work in small groups to solve it.

PBL has been developed and applied in a wide range of disciplines. The core model of PBL (Barrows, 1996) is composed of the following six characteristics.

- (1) Learning is student-centered. Despite the tutor's supervision, students must take all responsibility for their own learning, recognition of their need for better understanding, and handling of the search for information and sources, such as books, journals, and online resources.
- (2) Learning occurs in small student groups. In most early PBL sessions, these groups consist of five to nine students. At the end of each course of study, the students are assigned randomly to new groups with new tutors. This approach gives them more practice in studying effectively with different groups of students.
- (3) Tutors are facilitators or guides. The role is better understood with regard to metacognitive communication. The tutor asks her/his students different sorts of question that they are supposed to be asking themselves to enhance their understanding and enable them to handle problems more efficiently. Ultimately, the students take on this role, stimulating each other. The non-expert tutor concept, which holds that tutors should lead units in which they are not experts, was introduced to prevent tutors from returning to the old teaching method of giving students direct information and guidance. Tutors should, however, be experts in the difficult role of teaching.
- (4) Problems form the organizing focus and stimulus for learning. In PBL for health and medical education, patient and public health problems are presented in various formats, such as written case scenarios, simulated



patients, computer simulations, and video clips. This approach challenges students in practice, underscores the importance of learning, and motivates them to learn; they try to understand the problem from the perspective of other subjects, such as basic sciences. Thus, the problem requires them to focus on integrating knowledge from many disciplines to obtain particular information.

- (5) Problems are a vehicle for the development of problem-solving skills. For example, in health education, a patient problem is introduced in the same way as in real life. The layout of the problem should allow the students to ask questions of the patient, perform physical examinations, and request laboratory tests. Students should obtain the results of these investigations as they work through the problem.
- (6) New information is attained through self-directed learning. Students are likely to learn and gather expertise through their own studying and research, as professionals do. Students work together, discussing, reviewing, comparing, and debating what they have learned in the course of this self-directed learning (Barrows, 1996).

## 8. PBL and student motivation

Many supporters of PBL presume that this teaching method is very motivating for students. Particular features of PBL, such as working on real-life problems as an individual in a small group under intermittent supervision, likely encourage student motivation and learning. Motivation operationalizes students' circumstantial interest, which is interest prompted by environmental stimuli, such as the problem or the facilitator's discussion of an interesting fact (O'Grady et al., 2012).

Few empirical studies have explored how PBL affects students' motivation to learn. Intrinsic interest was the motivational factor that can be measured for the given topic. For example, Schmidt and Moust (1995) were the first researchers to test a path model in investigating associations among PBL features, such as the quality of problems and tutors, group functioning, intrinsic interest, and time spent on self-study. Group functioning refers to the ways in which students interact with others in their PBL groups, including the level of teamwork and whether group discussions are interesting. The outcomes, in terms of motivation students by their tutor, were linked positively to intrinsic interest in the topic (Schmidt and Moust, 1995). These results have been confirmed in other studies, which have found a strong association between group functioning and intrinsic interest in the topic. These findings indicate that the way students work together in groups, such as by creating learning objectives, playing around with ideas and assumptions that may clarify the facts introduced in the problem, helping group members, and giving explanations, has a positive effect on students' perceived interest in a topic (O'Grady et al., 2012).

## 9. The tutor's role in PBL

The role of the tutor in PBL has been a matter of heated debate; some scholars argue that the tutor must be an expert in the subject taught, whereas others believe that the tutor

should be only a facilitator of learning (Davis et al., 1992; Schmidt et al., 1993). In one study, students tutored by staff members usually performed better on final examinations than did those taught by peers, although the differences were small. Another study showed that student tutors performed differently from staff tutors, in that they showed a better understanding of the nature of the problems that students face when trying to learn about a particular problem. Moreover, student tutors show more special interest in their students. Staff tutors show more overuse of their expertise in the subject of a problem. In terms of the skills needed for small-group teaching, one study showed that students and staff members gave similar importance to the use of a teaching style that lets students deal with the tutorial discussion process. Both groups of students felt that tutors should perform as role models in terms of motivating critical thinking and reflection (Schmidt, 1995). Students mainly highlighted the importance of tutors' expertise in the topic of the problem (Schmidt, 1995).

The role of the tutor changes from information presenter to problem-solving session facilitator. Tutors monitor students by supervising discussion and asking questions that lead accuracy, relevance, prompting students to search for information to analyze the problem, and encourage participation of the whole group. Thus, tutors guide students to learn key concepts, facts, and processes linked to the course unit. PBL tutors must find or create suitable and helpful problems based on clear learning outcomes (Allen et al., 2011).

The successful implementation of PBL depends on the tutor's framing of active student learning and building on knowledge. For instance, PBL tutors can prepare mini-lectures to help students find missing information or useful resources, to dig deeper into particular topics. Tutors can also join discussions by listening and asking questions (Hmelo-Silver et al., 2007).

## 10. Assessing PBL

The assessment of PBL is challenging, as students are given autonomy to set learning goals that may or may not meet the tutor's expectations. In a previous study, progress testing theory was used for PBL assessment (Schmidt, 1995). Progress tests were administered to all students in a particular course, and the researchers then tried to evaluate knowledge gained over a long period of time, instead of that acquired in a short period of time before an examination. A memorization-oriented learning style was correlated negatively with meaningful learning, while the accomplishment on progress tested was correlated positively with meaningful learning (Schmidt, 1995).

One difficulty in evaluating PBL is that the process used to solve a problem and the solution reached are equally important. In addition, social interactions in a PBL group are complex; they unfold in sequence over time. Evaluation of the acquisition of such skills is quite difficult. For instance, knowledge evaluations have been used to assess students in PBL courses, but this approach does not effectively capture the acquisition of collaboration skills during PBL. Assessment by facilitators might be better, but it could affect group harmony. Moreover, the issue can be even more complicated when students have worked as facilitators or co-facilitators (Albanese and Dast, 2014).

## 11. Effectiveness of PBL

The claims made for PBL indicate improvement in higher-education outcomes (Gijbels et al., 2005). The results of studies exploring the influences of PBL are conclusive about the ability of students to solve problems (Gijbels et al., 2005).

An understanding of effective teaching is necessary to ensure the quality of dental education. This understanding must incorporate the skills and practices of effective teaching staff and the ways in which teaching is practiced in overlapping and various contexts (Devlin and Samarawickrema, 2010).

Allen et al. (2011) argued that PBL methods improve the effectiveness of student learning, enhance student performance in challenging tasks, and promote better knowledge retention. PBL appears to have strong effects on learning and accomplishment compared with other approaches in which learning is not based on problem solving. Students taught using PBL have shown superior learning acquisition compared with those taught under control conditions, in which problems were not the focus of attention and students were not encouraged to use their prior knowledge (Schmidt et al., 2011).

The PBL process can initially appear discouraging to those exposed only to traditional teaching methods. In the beginning, students in groups have contradictory views about the problem and its meaning. These perspectives must be investigated further to reach a shared understanding of the problem under discussion. This stage is difficult for students who are new to this approach, as they are not used to stating their views and may be unwilling to argue with other group members. On the other hand, students who are not stimulated to clarify their understanding and attitudes from the beginning will suffer at a later stage (Campbell and Norton, 2009).

Several studies have examined the learning outcomes associated with the traditional lecture-based approach. The results demonstrate that this method can effectively provide students with required knowledge; other methods, however, may be more effective. Moreover, in comparison with other methods, traditional lectures are not ideal for teaching skills or changing students' attitudes (Jeffries, 2014). These results point to the benefit of reducing the number of lecture hours in health and medical curricula, replacing them with more effective teaching methods, such as PBL (Jeffries, 2014).

PBL students and facilitators affect and challenge each other in different ways, related to aspects such as their opinions about what is considered to be knowledge, the content and process of interaction, and dealing with conflict within the group. Most groups try to achieve the learning objectives of the topic as a minimum, due to the students' dynamics and the facilitator's academic position (Savin-Baden and Major, 2004).

Several studies have compared the effectiveness of PBL and traditional teaching methods in improving lifelong learning skills. Some of these studies, particularly those focusing on medical education, have explored clinical performance skills; they have shown that students in PBL courses perform better than those in traditional learning settings in most cases. Furthermore, students who had acquired knowledge to solve problems were found to be more prone to use their knowledge spontaneously to solve new problems than were those who

had acquired the same information in traditional learning settings, such as lectures. Some researchers have proposed that students in PBL courses develop greater clinical competencies. Moreover, one study showed a significant difference in performance on an ethics PBL task in Harvard medical students (Savin-Baden and Major, 2004). Another study conducted in the context of a dietetics and nutrition course showed that students in PBL groups developed greater thinking ability and problem-solving skills than did those instructed using traditional methods (Savin-Baden and Major, 2004).

Data on the influences of PBL are affected by the way in which students' skills and knowledge are assessed. The effectiveness of PBL will likely be more apparent when adequate assessment methods are used (Dochy et al., 2003). When assessment depends only on factual recall, the success of PBL as part of a curriculum appears to be questionable. Assessment should obey the basic rules of testing students in association with curriculum outcomes, and should incorporate a suitable variety of methods (Wood, 2003).

PBL may be used as the backbone of an entire curriculum or as the chosen approach for some courses. A course can be designed to involve mixed teaching methods (including PBL) to attain learning outcomes, including students' skills, knowledge, and attitudes. Complementary lectures may be appropriate to introduce new topics or to deliver overviews of challenging topical material in combination with PBL problems. Furthermore, adequate time should be given each week for students to work on self-directed learning (Wood, 2003).

Although no single approach to dental education can be deemed to be optimal, the PBL approach has been found to be highly successful, mainly in the fields of health and medicine. This success is due to the development of students' cognitive and research skills, and underlies the increasing popularity of PBL throughout the world. It has also become common in other disciplines, such as engineering, agriculture, law, business, and computing. Many consider PBL to stimulate the development of a deeper learning approach, which remains with students throughout their lives (Campbell and Norton, 2009).

## 12. Summary

In conclusion, evidence clearly supports the effectiveness of PBL in dental education. Through PBL, students learn to become associates in the teaching and learning processes; they take responsibility for their learning, successfully work as part of a team, cope with new and changing circumstances, and acquire lifelong learning skills. Therefore, PBL can improve the critical thinking of dental students, teaching them to analyze and solve real problems, which prepares them for their future careers. This remarkable development in teaching approaches has improved the effectiveness of teaching in dental education institutes.

## Conflict of interest

The author declares that he has no conflict of interest associated with the material used in the current article and no financial interest as well.

## References

- Albanese, M., Dast, L., 2014. Problem-based learning. In: Huggett, K. N., Jeffries, W.B. (Eds.), *An Introduction to Medical Teaching*. Springer, Netherlands, pp. 57–68.
- Allen, D.E., Donham, R.S., Bernhardt, S.A., 2011. Problem-based learning. In: *New Directions for Teaching and Learning*, vol 128, pp. 21–29.
- Atkins, M., Brown, G., 2002. *Effective Teaching in Higher Education*. Routledge.
- Barrows, H., 2002. Is it truly possible to have such a thing as dPBL? *Distance Educ.* 23 (1), 119–122.
- Barrows, H.S., 1996. Problem-based learning in medicine and beyond: a brief overview. In: *New Directions for Teaching and Learning*, 68, pp. 3–12.
- Barrows, Howard S., Tamblyn, Robyn M., 1980. *Problem-Based Learning: An Approach to Medical Education*. Springer Publishing Company.
- Biggs, J., Tang, C., 2011. *Teaching for Quality Learning at University*. McGraw-Hill International.
- Bridges, S., McGrath, C., Whitehill, T.L., 2012. *Problem-Based Learning in Clinical Education: The Next Generation*, Vol. 8. Springer.
- Campbell, A., Norton, L., 2009. *Learning, Teaching and Assessing in Higher Education: Developing Reflective Practice*. Learning Matters Ltd..
- Davis, W.K., Nairn, R., Paine, M., Anderson, R., Oh, M., 1992. Effects of expert and non-expert facilitators on the small-group process and on student performance. *Acad. Med.* 67 (7), 470–474.
- Dennick, R., Exley, K., 2004. *Small Group Teaching: Tutorials, Seminars and Beyond*. Routledge.
- Devlin, M., Samarawickrema, G., 2010. The criteria of effective teaching in a changing higher education context. *Higher Educ. Res. Develop.* 29 (2), 111–124.
- Dochy, F., Segers, M., Van den Bossche, P., Gijbels, D., 2003. Effects of problem-based learning: a meta-analysis'. *Learn. Instr.* 13 (5), 533–568.
- Gijbels, D., Dochy, F., Van den Bossche, P., Segers, M., 2005. Effects of problem-based learning: a meta-analysis from the angle of assessment. *Rev. Educ. Res.* 75 (1), 27–61.
- Hmelo-Silver, C.E., Duncan, R.G., Chinn, C.A., 2007. Scaffolding and achievement in problem-based and inquiry learning: a response to Kirschner, Sweller, and Clark. *Educ. Psychol.* 42 (2), 99–107.
- Jeffries, W., 2014. Teaching large groups. In: Huggett, K.N., Jeffries, W.B. (Eds.), *An Introduction to Medical Teaching*. Springer, Netherlands, pp. 11–26.
- Loyens, S.M., Kirschner, P., Paas, F., 2011. Problem-based Learning. In: Harris, K.R., Graham, S., Urda, T. (Eds.), *APA Educational Psychology Handbook*, Vol 2. American Psychological Association, Washington.
- O'Grady, G., Yew, E.H.J., Goh, K.P.L., Schmidt, H.G., 2012. *One-Day, One-Problem*. Springer Verlag.
- Onyon, C., 2012. Problem-based learning: a review of the educational and psychological theory'. *Clin. Teach.* 9 (1), 22–26.
- Polyzois, I., Claffey, N., Mattheos, N., 2010. Problem-based learning in academic health education. A systematic literature review. *Eur. J. Dent. Educ.* 14 (1), 55–64.
- Rahman, G., 2011. Use of computers among students of dental college in Saudi Arabia. *J. Educ. Ethics Dent.* 1 (1), 12–17.
- Savin-Baden, M., Major, C.H., 2004. *Foundations of Problem-Based Learning*. McGraw-Hill International.
- Schmidt, H., 1995. Problem-based learning: an introduction. *Instr. Sci.* 22 (4), 247–250.
- Schmidt, H.G., 1993. Foundations of problem-based learning: some explanatory notes. *Med. Educ.* 27 (5), 422–432.
- Schmidt, H.G., Moust, J.H., 1995. What makes a tutor effective? A structural-equations modeling approach to learning in problem-based curricula. *Acad. Med.* 70 (8), 708–714.
- Schmidt, H.G., Rotgans, J.I., Yew, E.H., 2011. The process of problem-based learning: what works and why'. *Med. Educ.* 45 (8), 792–806.
- Schmidt, H.G., Van der Arend, A., Moust, J.H., Kokx, I., Boon, L., 1993. Influence of tutors' subject-matter expertise on student effort and achievement in problem-based learning. *Acad. Med.* 68 (10), 784–791.
- Walton, H.J., Matthews, M., 1989. Essentials of problem-based learning. *Med. Educ.* 23 (6), 542–558.
- Wood, D.F., 2003. Problem based learning. *BMJ* 326 (7384), 328–330.
- Wood, E., 2004. Problem-based learning: exploiting knowledge of how people learn to promote effective learning. *Biosci. Educ.* 3.